THE ESSENTIAL CHARACTERISTICS OF UNITED STATES CLIMATES[1]

By Professor ROBERT DeC. WARD
HARVARD UNIVERSITY, CAMBRIDGE, MASS.

Climatic Provinces of the United States.—For purposes of general description, it is convenient to subdivide the United States into certain climatic districts or provinces. The largest, or *Eastern,* extends from the eastern margin of the Great Plains, which roughly coincides with the 20 inch annual rainfall line and also with the 100th meridian, to the Atlantic Ocean, and southward nearly to the Gulf of Mexico. The strip bordering on the Gulf may be set apart as a subordinate district, the *Gulf* province. The *Plains* province includes the Great Plains proper, and extends westward to the Rocky Mountains. Between the Rocky Mountains and the Sierra Nevada-Cascade ranges comes the *Plateau* province. The Pacific Slope constitutes a natural climatic region which may be called the *Pacific* province.[2]

The differences between north and south, resulting from differences in latitude, suggest a further subdivision of the Plains, Plateau, and Pacific provinces into northern and southern sections. Similarly, the Gulf province occupies the more southern latitudes of the Eastern province.

The Eastern Climatic Province.—The Eastern Province, enormous as is its extent, is nevertheless characterized by great uniformity in its climatic conditions and in its weather types. It has a continental climate, but with abundant, or at any rate sufficient rainfall. Over most of it the seasons are strongly contrasted. The summers are very warm and the winters cold. But the hot summers, with sufficient rainfall, usually insure abundant harvests, and the cold winters, while severe in northern sections, are on the whole stimulating and tonic. The influence of the Atlantic Ocean is minimized by the fact that the prevailing winds are off-shore throughout the year, being north-

[1] Reference may be made to the following papers by the same author: "Two Climatic Cross-Sections of the United States," *Mo. Wea. Rev.*, Vol. 40, 1912, pp. 1909–1917; "Lorin Blodget's 'Climatology of the United States.' An Appreciation," *ibid.*, Vol. 42, 1914, pp. 23–27.

[2] See R. DeC. Ward, "Climatic Subdivisions of the United States," *Bull. Amer. Geogr. Soc.*, Vol. 47, 1915, pp. 672–680.

west in winter over much of the coast, and southwest in summer. Thus it follows that there can be but little of the tempering effect usually associated with conservative ocean waters, and the coastal belt, except when the wind blows onshore under general cyclonic or anticyclonic controls, or when, in summer, local sea breezes occur, does not differ very much from the interior. One aspect of this situation is clearly illustrated on the chart of equal annual ranges of temperature. The large ranges of the interior are carried eastward to the coast, and even on to the ocean for some distance offshore. The continentality of the Atlantic coast climate, with its slight marine modifications, was well described by Blodget when he wrote that on the immediate coast "a local oceanic climate exists, but it is always blended with the continental features which belong to this part of the continent generally."[3]

There are only relatively slight and unimportant differences of topography. The whole area is freely open, to Canada on the north; to the Atlantic Ocean on the east; to the Gulf of Mexico on the south. With the warm Gulf on the south and the cold Canadian plains on the north, the winter temperature-gradients between north and south are unusually steep. In January, the isotherms over the eastern United States are very closely crowded together. The temperature then decreases northward at the rate of 2.7° Fahr. in each degree of latitude, both on the Atlantic coast and in the Mississippi Valley. This is an extraordinarily rapid temperature-gradient, and may be contrasted with the very much weaker gradient along the western coast of Europe in winter. As seen on the chart of mean annual temperatures, one may go north in western Europe a distance of a thousand miles without finding a change of temperature as great as that met with in half as long a journey along the eastern coast of the United States. In summer, North America is well and relatively very uniformly warmed. There is then much less difference of temperature between south and north. The temperature-gradient is greatly weakened. It becomes 1.1° along the eastern coast, and 0.7° in the Mississippi Valley. The temperature conditions may be very briefly generalized as follows:

District	Mean Annual	Jan.	July	Abs. Max.	Abs. Min.
N	40°	5°–10°	65°	100°–105°	—40° to —50°
S	65°–70°	50°–55°+	80°+	105°	zero–10°

The average dates of first and last frost, broadly generalized, are as follows:

[3] Lorin Blodget, "Climatology of the United States," 1857.

District	Last Spring	First Autumn	Av. Length of Growing Season
N	After June 1 (extreme N.)	Sept. (extreme N.)	3–4 months
S	Before March 1	November	7 months and over

Besides having a great uniformity of temperature conditions, considering its extent, the eastern climatic district of the United States also has, as a whole, a plentiful rainfall, well distributed throughout the year. Disregarding local areas on the mountains, the annual rainfall is greatest (50 + inches) towards the Gulf, and on the South Atlantic coast, most of the supply of water vapor for this precipitation coming from the Gulf and Atlantic Ocean, and decreases from about 40–45 inches over much of the north and central Atlantic coast and Ohio valley to 30–40 inches over the prairies, and 20 inches at about the 100th meridian. Although the rainfall is comparatively small at the western margin of the district, it is very well apportioned through the year. The maximum over the great farming states of the Mississippi valley region comes when it is most needed, *i.e.*, in the growing season of late spring and early summer. Of this region it has been well said:

> Although droughts sometimes affect considerable districts, and floods occasionally devastate the larger valleys, yet the world hardly contains so large an area as this so well adapted to civilized occupation.[4]

Nowhere in this district is there permanent necessity of irrigation, as there is in many places farther west. The rainfall comes chiefly from the ordinary cyclonic storms of the prevailing westerly winds. The spring and early summer rainfall of the Mississippi valley and adjacent regions is largely a local thundershower rain, and naturally occurs with the greatest frequency during the warmer months. In the colder season, with high pressures and with winds prevailingly blowing out from the continent, there is less opportunity for precipitation. In late summer the rainfall along the Gulf and Atlantic coasts is generally at a maximum, for the inflowing winds are then very warm and moist, and there are many thunderstorms. Along these coasts occasional West Indian hurricanes, in August, September, or October, give heavy rains and not infrequently damage buildings and crops. In Florida, the heavy August and September rains are almost tropical in character. In Tennessee and adjacent parts of Mississippi, North Carolina, Georgia, and Alabama there is a late winter or early spring maximum of precipitation.

[4] W. M. Davis, "Elementary Meteorology," page 301.

Rain falls most often, and hence the number of rainy days and the rain probability are greatest, in the Great Lakes region. This same district is also more cloudy than any other portion of the country except the northwest coast. The explanation of these conditions is found in the frequency of cyclonic storms, accompanied by general rains and by extended cloud sheets, over the Great Lakes and along the St. Lawrence Valley. Snow falls throughout a long season and in considerable amounts over these same northern and northeastern sections. Towards the south, the snow season becomes shorter and shorter; the snow lies on the ground less and less time. It finally becomes an almost, and then an entirely negligible factor.

Rapid and marked weather changes are characteristic of the eastern United States. These "paroxysms of change" (Blodget), which occur during the passage of numerous well-developed cyclonic storms, are unique for their suddenness, frequency and amount, especially in winter. They result from the bringing together, around the passing low-pressure centers, of winds of different directions and of very different temperature and moisture conditions, depending upon the characteristics of the regions from which these winds come. The winter dry northwest winds are often piercingly cold, coming as they do directly from the cold continental interior, and may cause a fall of temperature of 30° to 50° Fahr. in twenty-four hours, reducing the temperature to zero or lower ("cold waves"). They blow on the rear of cyclonic storms, and follow warmer and damper southerly or easterly winds which bring rain or snow. Several short periods of extreme cold are to be looked for every winter. During the warmer months, similar northwest winds bring the summer cool spells. The warmest weather, in winter as in summer, is brought by southerly and southwesterly winds which, coming from lower and warmer latitudes, blow north into a passing storm-center. In winter these southerly spells, while "unseasonably" warm, serve to break the monotony of the cold. In summer, with its high temperatures and high relative humidity, this same "sirocco" weather type is uncomfortably muggy and depressing, and often brings sunstrokes. The summers always bring spells of extreme heat of this type. In winter, the northeast cyclonic winds on the northern Atlantic coast are damp and unpleasantly chilly, blowing onshore from the cold ocean waters. In summer, their low temperatures bring welcome relief from the heat. In such a region, where sudden and irregular weather changes are so characteristic, climatic averages can give little

idea of the actual conditions which are experienced from day to day. Seasons often differ markedly in character from year to year. Weather changes are erratic and unexpected. It has become a popular saying that almost any kind of weather may be expected at any time of the year.

Thunderstorms, many of them of wide extent and of great violence, are characteristic summer phenomena over the eastern and southern United States. The far more severe tornadoes, fortunately of much less frequent occurrence, develop most often over the great lowlands of the central and upper Mississippi and of the lower Missouri Valleys. Tornadoes, as well as the more violent thunderstorms, have a habit of springing up along the dividing ("wind-shift") line between the warm southerly ("sirocco") type of weather in front of a passing summer cyclonic storm and the cool northwesterly (summer cool wave) type on its rear.

The Gulf Province.—Over the southern tier of States bordering on the Gulf of Mexico the temperatures are higher; the winters are much milder; the summers are longer and hotter; the rainfall is heavier, and has a late summer or early autumn maximum. With increasing distance from the most frequented cyclonic paths, which follow along the northern border of the United States, the cyclonic control is weaker; the irregular wind, temperature and weather changes are fewer, less sudden, and less emphatic; the diurnal phenomena are more marked, even in winter; the weather is more stable; conditions are more settled. In winter, cyclones which give heavy snows and marked wind changes followed by cold waves over northern sections, often bring but little cloud and rain, without marked temperature variations, over the Gulf States. The southern States are, nevertheless, subject to occasional invasions of considerable cold in winter, during the prevalence of north and northwest winds on the rear of well-developed cyclonic storms. These winter cold waves sweep east and southeast as far as the southern Atlantic and Gulf coasts, but their intensity diminishes rapidly as they advance into more southern latitudes. The occurrence in districts of high mean annual temperature of frosts of sufficient severity to injure the more sensitive crops, is a characteristic of southeastern North America, and is one of the marked, and economically one of the most unfortunate, features of the climate of the Gulf Province, which is otherwise in many ways singularly favored. Snow becomes a rarity. Over the sections immediately adjacent to the Gulf, it is practically negligible. On the warm, damp lowlands there is the

wealth of southern cotton, and sugar cane, and semi-tropical fruits, and from the truck gardens of the southern Atlantic coast immense quantities of early vegetables are shipped north, by rail and by water, to the markets of the great northern cities. The severe winters in the north effectually put a stop to most outdoor occupations during the colder months, although giving rise to others, such, *e.g.*, as ice-cutting and lumbering. In the Gulf Province, on the other hand, and over the closely adjoining sections of the Eastern Province, most agricultural and other outdoor work can be continued throughout the year.

The Plains Province.—The essential difference between the climate of the Great Plains and that of the Eastern province is not so much one of general temperature conditions as of rainfall. The Plains, like the rest of the great region lying to the eastward, have a continental climate. They lie at a distance from large bodies of water, and have massive mountain barriers on the west, between them and the Pacific Ocean.

The following table summarizes the temperatures:

District	Mean Annual	Jan.	July	Abs. Max.	Abs. Min.
N	40°	0°–10°	65°–70°	105°–110°	—50° to —60°
S	65°	40°–50°	80°–85°	110°	zero

As compared with the eastern States, the Plains have larger diurnal ranges of temperature; more abundant sunshine; drier air; greater evaporation; smaller rain probability; less rain; more wind. The prevailing winds have a monsoonal character: they are northerly and northwesterly in winter and southerly and southeasterly in summer. There is a well-marked diurnal variation in velocity on days whose weather is not under strong cyclonic control.

Rainfall is the fundamental climatic factor. From the more abundant precipitation towards the Atlantic and Gulf, the mean annual rainfall decreases westward until, at the eastern margin of the Plains, it averages about 20 inches, and towards the western margin decreases still further to below 15 inches. No sudden change, either in topography or in climate, takes place along the 100th meridian, but where the mean annual rainfall averages less than 20 inches, the amount is too small, under ordinary circumstances, for permanently successful agriculture, on a large scale, without irrigation. Another disadvantage of a small rainfall is its variability from year to year. Remarkable results have been attained by "dry farming" methods over parts of the Plains, in the case of certain crops which require little water, and in seasons with favorable rain-

fall. Dry farming is, however, a precarious venture, and can not be counted on to give results comparable with those obtained in a well-watered or well-irrigated country. The natural limitations of the country are clearly recognized. Its best use is not to be found in the old-time boundless cattle ranges, nor in vast farms which depend solely upon the natural rainfall, but rather in smaller individual farms and cattle ranches, where irrigation from streams or from ground-water is possible. The relatively high and steady velocities of the winds over the Plains have proved a reliable source of power in driving the windmills which are widely used for pumping water for irrigation. This relation of the 20 inch rainfall line to agriculture has locally long been recognized. "East of it lies success; west of it, failure. Look out for the 'dead-line.'" The critical boundary thus termed the "dead-line" has played an important part in the settlement and development of the Great Plains.

The distribution of the rainfall in normal years is singularly favorable over most of the Plains province. The maximum usually comes in late spring or early summer, when moisture is most needed by the growing crops. To the southward (New Mexico), the maximum is retarded until mid- or late summer. These warm-season rains are spasmodic, and fall chiefly in the form of brief and local thundershowers. Winter is the dry season. In the north, the winter precipitation is mostly in the form of snow, but the amounts are considerably less than those of the same latitudes farther east. Over the southern Plains, where the winters are warmer, the winter snows average under 10 inches in depth, and are even under 5 inches in western Texas and southernmost New Mexico.

Cyclonic control is less marked than in the east, partly because fewer cyclonic storms pass over or near the Plains, and partly because the storms are generally of a milder type. Irregular weather changes are most frequent over the northern Plains States, which are nearer the main storm track. In the south, the sequence of weather changes is much more uniform. Diurnal rather than cyclonic controls are dominant most of the year. The more severe winter cyclones bring sudden temperature changes, severe gales, driving snow and extreme cold ("blizzards"). Cold waves, sweeping southward and eastward from western Canada, occasionally reach as far south as Texas, where they cause sudden and marked falls in temperature, with chilling northerly winds ("northers"). Much of the winter weather, however, is dry, clear, settled and bracing. Locally, along the eastern base of the Rocky Mountains, the

winter cold is often tempered by warm *chinook* winds. Long spells of hot, dry, typical, diurnal weather, with southerly winds, are characteristic of much of the summer. When continued for many days, or sometimes even for weeks, unbroken by general rains or by widespread thundershowers, such spells are associated with extended droughts and result in injury to crops, especially when accompanied by certain hot and dry winds which are characteristic of the Great Plains ("hot winds"). While thunderstorms are of frequent occurrence during the warmer months, tornadoes are relatively rare.

On the west, the Plains province gradually merges into the eastern foothills and slopes of the Rocky Mountains. Here the greater elevations and the topographic irregularities give rise to special climatic features which are associated with mountain and plateau climates. Colorado has become famous for its health resorts. With a small annual rainfall; light winter precipitation; few storms; little cloudiness; dry, stimulating air, and comparative immunity from many of the sudden and severe weather changes characteristic of the east, there are evident advantages for invalids in this region.

The Plateau Province.—The *Plateau* province is a great interior region of very diversified topography. It has a wide range of mountain, high plateau and arid lowland climates, superposed upon and causing local modifications of the general dry continental climate of the province as a whole. "Climatological topography" (Blodget) is here highly significant. The diversity of topography results in a very "patchy" distribution of climates and of vegetation, as local variations of temperature, frost, rainfall, etc., may determine. The winds, also, are largely topographically controlled, both in the case of the local mountain and valley breezes and of the more general cyclonic wind directions.

The outstanding characteristic is the small rainfall, which, however, shows marked increase with altitude. The higher mountains and plateaus have distinctly more precipitation than the neighboring lowlands. With the exception of local areas in the mountains, the mean annual rainfall is everywhere less than 20 inches; it is mostly below 10 inches, and over no insignificant portion of the southwest it is even below 5 inches. This is the region of what, not many decades ago, was known as the "Great American Desert"; of Great Salt Lake; of the interior drainage basis of Nevada, the "artificial State." The real "American desert" is in southeastern California, southwestern Arizona and western Nevada. Death Valley is here, with

its famous borax and its intense summer heat. The Salton Sea is here—an anomaly in a true desert. The Black Rock desert; the "sinks," and the soda deposits of western Nevada are here. With the high mountain barrier on the west, the whole plateau district is in the rainshadow. Arid or semi-arid conditions are to be expected, except where the higher mountains or plateaus give rise to more plentiful precipitation, especially in the north, where general storms occur more frequently, and where the barrier is less effective. Even in the south, where the rainfall is less, the higher elevations are fairly well watered. The name of the Aquarius Plateau is a suggestive one. The Rocky Mountains are so far from the Pacific that their rainfall is not as a whole heavy. They are, furthermore, to leeward of the considerable ranges of the Sierra Nevada-Cascades.

Irrigation is made necessary by reason of the deficient rainfall, although dry-farming is carried on in certain sections, as, *e.g.*, in eastern Washington, with considerable success. Wherever the streams, supplied by the melting snows and the heavier rainfall of the higher mountains, afford sufficient water, there green oases of varied crops, dotted with fruit and shade trees, break the monotony of the "desert." Most of the winter precipitation is in the form of snow, which is decidedly heavier in the north than in the south, and over the higher elevations than over the lower lands. In the far southwest, snow is rarely seen except on the mountains. The rainfall distribution through the year varies greatly in different portions of the district. In the north, there is generally a late winter or early spring maximum. In the south, the primary maximum usually comes in late summer, with a secondary maximum in winter. The winter rains and snows are cyclonic. Frequent, often daily, thunderstorm rains are characteristic of the warmer months, especially over the mountains. The rain probability is below 20 per cent., and the minimum number of rainy days in the United States is found in the far southwest (under 30).

Temperatures are so largely controlled by the topography that even broad generalization is almost impossible. The essential facts may roughly be given as follows:

District	Mean Annual	Jan.	July	Abs. Max.	Abs. Min.
N	50°	25°–30°	65°–70°	100°–105°	—10° to —30°
S	60°–70°	40°–50°+	80°–90°+	110°–120°+	zero to 20°

Minimum temperatures and frost occurrence are mostly a matter of local topographic control and of local air drainage.

The dates of first and last frost are very variable. The summers of the southern lowlands are long and intensely hot, but the low humidity is an important factor in making the high temperatures endurable. The southern winters are comparatively mild, dry and bracing. In the north, the heat of the summer is much less severe, and the winters are colder. The districts west of the Rocky Mountains are, however, to a great extent protected against severe cold waves of the eastern type. Dry, stimulating air; an abundance of sunshine; large diurnal ranges of temperature—these are dominant characteristics of the Plateau climates, taken in the large. Diurnal ranges of 40° or more are by no means uncommon. Cool nights follow hot days in summer, especially on the mountains and plateaus. Periodic diurnal, rather than irregular cyclonic, weather types are dominant.

The Plateau province is beyond the reach of most of the cyclonic storms which so largely control the weather and climate of the rest of the country. At intervals, winter storms, coming from the Pacific, cross the northern portion of the district on their eastward course along the northern track, and other, but not greatly frequented, storm tracks cross the central and southern parts. Hence, as a whole, there is a decided lack of sudden, irregular and severe weather changes. The maximum cyclonic control, here as elsewhere, is in the colder months, but few of the winter storms bring heavy precipitation. Even in winter, long spells of fine, bright weather, with light winds, moderately warm days and cold nights are common. Summer weather is characteristically fine and settled, broken by afternoon or evening thundershowers, and occasionally by the cloud sheet and general rains of a passing summer cyclonic storm.

The Pacific Province.—Over the narrow Pacific coastal belt climatic conditions are quite unlike those elsewhere in the country, and in many respects resemble those of northwestern and western Europe, including the Mediterranean area. Blodget gave an excellent brief yet comprehensive climatic comparison when he wrote that "the Pacific coast climates are Norwegian, English and Spanish or Portuguese, with the intermediate France blotted out."[5] The similarity of climates in southern California and in the countries bordering upon the Mediterranean explains the similarity of many of the agricultural products and fruits, and of the general methods of cultivation, in these two regions. Exposed to the influence of the warm

[5] Lorin Blodget, *loc. cit.*

Pacific, with the prevailing westerly winds coming directly from the conservative ocean, and protected on the east by high mountains, the Slope as a whole has a modified marine or windward coast climate. A typical west coast subtropical climate is found in California. The wide range of latitude between north and south, together with the varying topographic controls and the differences of exposure to the ocean influences, explain the great variety of climates which are found in this province. These range from those of the rainy and densely forested slopes of Washington to those of semi-arid southern California; from those of the lowlands to those of the snow-covered mountain tops; from the cool summers of the coast to the hot summers of the Great Valley. The climate is, in general, mild and equable, with slight diurnal and seasonal ranges. The relatively small seasonal change is common both to the cool and humid climate of the far northwest and to the warm and dry climate of the southern interior.

The following table summarizes, in a very general way, the essential temperature characteristics of the Pacific province.

District	Mean Annual	Jan.	July	Abs. Max.	Abs. Min.
N	50°–55°	35°–40°	60°–65°+	95°–105°	10°–0°
S	65°±	50°–55°	65°–75°+	110°–115°	20°±–10°

The relatively high winter temperatures insure the Pacific coast harbors against freezing, whereas on the northern Atlantic coast ice not infrequently causes difficulty to navigation in severe winters. Further, the mountain barrier of the great Sierra Nevada and Cascade ranges to a large extent keeps out the extremes of winter cold which are found over the interior districts to the east. Under the influence of the warm ocean current eddy which circulates from right to left in the Bay of Alaska, and of the cool return current which flows along California and Mexico on its way equatorward, the isotherms along the Pacific coast are spread far apart. Hence there are but slight differences of temperature between north and south along the coast, and the rates of temperature-decrease per latitude degree from San Diego to Sitka are but 0.95° in January, 0.65° in July, and 0.8° for the year. These temperature-gradients may be compared with the much steeper gradients of the Eastern province, previously referred to. The chart of equal annual ranges of temperature shows clearly how small is the seasonal change of temperature along this coastal strip (not over 25°), while across the mountains, in the interior, the ranges reach 40°, 50° and even 60°. No such severe winter

cold waves are experienced here as to the east of the Rocky Mountains, or even over the Plateau. The area over which frost does not occur annually includes southern California. In the region around San Diego, killing frost occurs in less than half of the winters. The attractions of outdoor life during the colder months in southern California have made this locality a favorite winter resort for those who wish to escape the rigors of more severe northern latitudes.

The interior valley of California, between the Coast Range and the Sierra Nevada, being well shut off from the ocean, is very hot, dry and sunny in summer, especially in the south, while the immediate sea-coast is cool, damp and often foggy. The crowded July isotherms show very clearly the difference between the temperatures of the interior and those of the coast. This is one of the most remarkable contrasts in the world over so restricted an area. The strong diurnal ranges of temperature over the interior valley give relatively cool nights and the dryness of the air relieves the great heat of the days. The high inland summer temperatures result in the prevalence of cool onshore daytime winds, which are unusually well developed at San Francisco. Sea-breezes are a characteristic feature of the whole coast.

The rainfall is heavy (over 100 inches) on the northwestern coast of Washington, and decreases rapidly to the south, to about 10 inches on the extreme southern coast of California, and less than 10 inches in the San Joaquin Valley. There is a marked seasonal periodicity. The maximum comes in winter. General cyclonic storms are then most frequent; they then travel farther south; the land is colder than the ocean; the prevailing winds have more of a southerly component. Some southern districts are actually without any rain in summer, and then become very dry and dusty. In the north, however, it rains more or less all through the summer months, although the winter maximum remains. The rainfall migrates from north to south as winter approaches, *i.e.*, the rains in the south are distinctly subtropical in character, and correspond to the winter rains of the Mediterranean districts of Europe. As Woeikof first pointed out, these rains extend farther north in western North America than happens anywhere else in the world.[6] The rains come when the "stormy westerly winds" are farthest south, and cease when the northward migration of the tropical high pressure belt displaces the storm-bearing westerlies polewards. Even in the so-called "rainy season"

[6] A. Woeikof, "Die Klimate der Erde," 1887, p. 24.

of winter, the rains are generally light; they are not steady and continuous, usually lasting but two or three days and separated by spells of fine, sunny weather. On the extreme northwest coast, rain falls on nearly half of the days in the year. There is a marked decrease in the number of rainy days, as well as in the mean annual rainfall, from north to south. From the point of view of an outdoor life, southern California is favored in having very few rainy days. Over the lowlands of the Pacific Slope, snowfall is of little importance. Even in the north it is very light, and on the coast it becomes practically a negligible factor south of the northern boundary of California. On the mountains, however, even in southern California, snow falls frequently, and on the western slopes of the high Sierras and of the Cascades it is very heavy. The water-supply from these melting mountain snowfields is of supreme importance in irrigating the fertile and productive valleys and lowlands, whose natural water supply, in the form of rainfall, is insufficient for agriculture and for fruit-raising.

The Pacific Slope is not subjected to violent weather changes. During the winter, a series of general cyclonic storms moves eastward across the northern portion of the province, and occasional storms come in farther south, or their paths carry them south to the more southern latitudes. Hence the northern districts have more rain, more cloud, and more frequent weather changes than the southern. The amount and distribution of the annual rainfall are controlled by the number, intensity and paths of the winter storms. When these extend farther southward, and are better developed, the rainfall is heavier and more widely distributed. In general, rain falls with the cyclonic winds in the southern quadrants, and fair weather prevails with northerly cyclonic winds. The changes in wind direction bring changes of temperature, but the general temperature gradient being weak, and the regions from which the different winds come not differing greatly in temperature, sudden and marked rises and falls of the thermometer do not occur. In general, southerly to westerly winds are warm in winter and cool in summer; northerly to easterly winds are cool in winter and warm in summer. The rains of summer, where they occur, are as a rule light and local in character, and fall mostly in the north and on the mountains. The cold-season precipitation comes in the form of general cyclonic rainy spells. Thunderstorms are infrequent, and usually light; rarer on the coast and more common inland and on the higher mountains. Special cyclonic winds, having certain marked

peculiarities, occur over some sections, under the combined control of the pressure distribution and of the topography. The "northers" of the great valley of California have a chinook or foehn character. They are dry and dusty and may be injurious to crops. The "Santa Ana" of southern California is also a hot, dry and dusty wind, somewhat similar to the norther. It blows from northerly or easterly points, and is trying to men and animals. Coming from the dry interior, it reaches the southern coast with the characteristics of a desert wind.

The Valley of California is a great agricultural and fruit-raising district, as is the Willamette Valley in Oregon. The summer dry season is a favorable climatic feature during harvest-time, and for drying fruits in the open air. The western slopes of the Sierra Nevada are well watered and forested, while the eastern (leeward) slopes are dry. On the Cascades and on the northern Coast Range there are also abundant forests. North of San Francisco, on the western slope of the Coast Range, are the famous redwood trees, and the "Oregon pine," from farther north, has been known the world over because of its usefulness for ships' masts and spars.

BIBLIOGRAPHIC NOTE.—For general statistical information concerning all parts of the United States reference may be made to the "Summaries of Climatological Data by Sections" (*Bulletin W*, U. S. Weather Bureau, 4to, Washington, D. C., 1912. 2 vols. Price 5 cents for each section; 10 cents for any three sections; $3 for entire set unbound. To be obtained from the Superintendent of Documents, Washington, D. C.) The period covered by the data varies. Reprints are issued from time to time for the various sections, containing all the data included in the first edition and also bringing the observations down to later dates. Several important additions to the tables have also been made in the reprints. (See also, R. DeC. Ward, "A Short Bibliography of United States Climatology," *Journ. Geogr.*, Vol. 17, Dec., 1918, pp. 137–144.)